Topic B – Part 3 Carbohydrates!

IB Chemistry

Topic B – Biochem

B3 Carbohydrates - 3 hours

- B.3.1 Describe the structural features of monosaccharides. (2)
- B.3.2 Draw the straight-chain and ring structural formulas of glucose and fructose. (1).
- B.3.3 Describe the condensation of monosaccharides to form disaccharides and polysaccharides. (2)
- B.3.4 List the major functions of carbohydrates in the human body. (1)
- B.3.5 Compare the structural properties of starch and cellulose, and explain why humans can digest starch but not cellulose. (3)
- B.3.6 State what is meant by the term dietary fiber. (1)
- B.3.7 Describe the importance of a diet high in dietary fiber. (2)

B3.1 – Structural Features of Monosaccharides

- **Monosaccharides** are simple sugars that contain a carbonyl group (>C=O) and two or more hydroxyl groups (-OH).
- **Glucose**, $C_6H_{12}O_6$, is the most common monosaccharide and is the **monomer** for the **polysaccharides** starch and cellulose.
- Monosaccharides contain:
  - 3 or more carbon atoms with carbon skeleton
  - If carbonyl is at the end = **aldose** (glucose)
  - If carbonyl is at any other position = **ketose** (fructose)
- All are white, crystalline solids soluble in water due to the –OH group which is polar for hydrogen bonding

B3.2 – Glucose and Fructose

- You are required in B3.1 to **describe** the features of monosaccharides
- In B3.2 you must be able to **draw** both the **straight-chain** and **ring** structural formulas of glucose and fructose

B3.2 – Aldose vs Ketose

- Glucose (Fig 22.38) and Fructose (Fig 22.39) are both simple monosaccharides with a formula of $C_6H_{12}O_6$ with two forms; acyclic ('straight chain') and cyclic ('ring') structures.
- Below are the acyclic structures of each, on the next slide you will find cyclic structures which are heavily favored in equilibrium

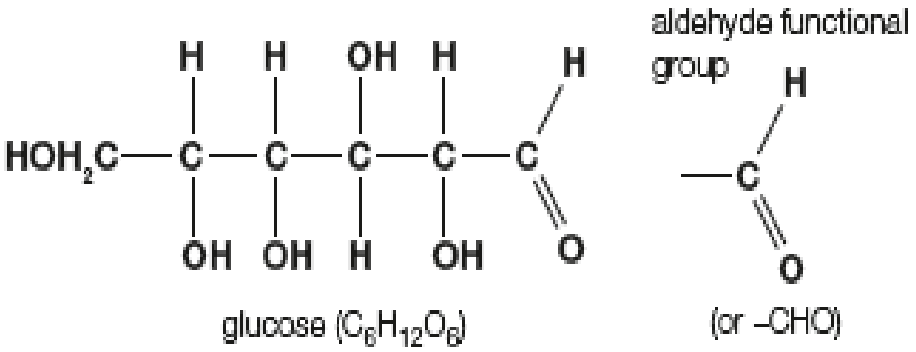


Figure 22.36 The structure of D-glucose, an aldose

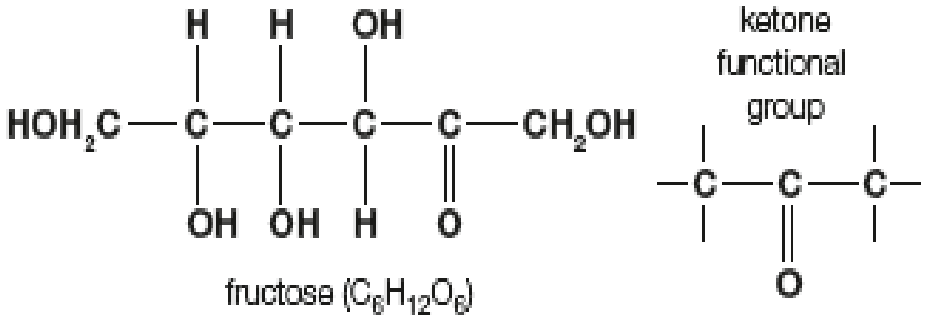
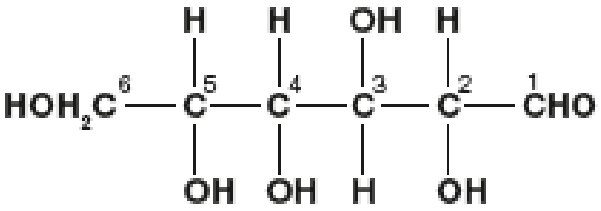


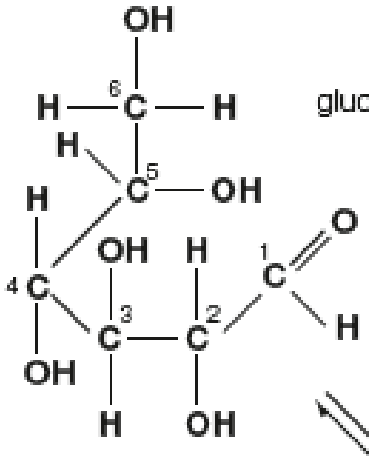
Figure 22.37 The structure of D-fructose, a ketose

B3.2 – Formation of **Cyclic Glucose**

for convenience in describing reactions the carbon atoms are numbered

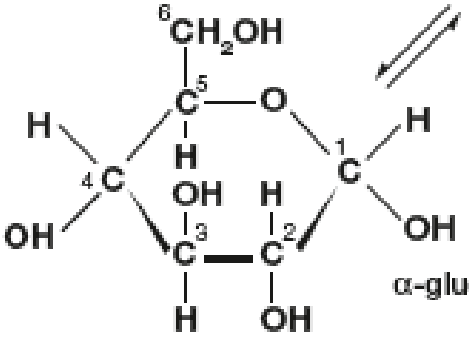


glucose, straight-chain form



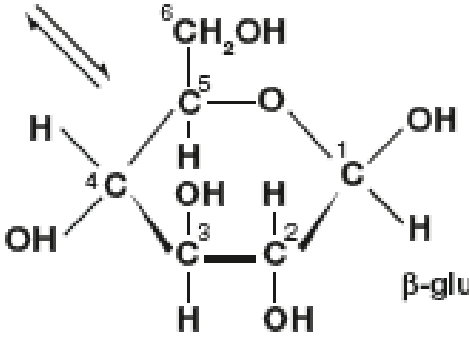
glucose, folded

the two forms of glucose depend on the positions of the –H and –OH attached to the carbon-1 when the ring closes



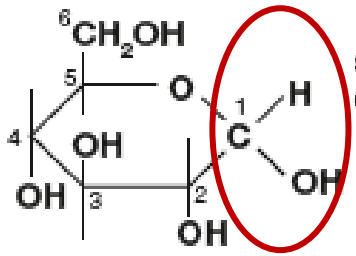
α-glucose

glucose in pyranose rings



β-glucose

for simplicity and convenience it is the skeletal formulas that are most frequently used in recording biochemical reactions and showing the structure of biologically active molecules



skeletal formula of α-glucose

skeletal formula of β-glucose

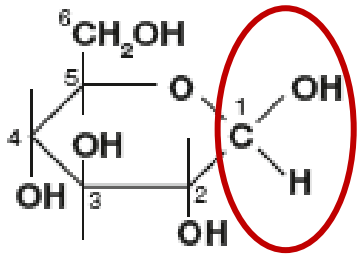


Figure 22.38 The structures of glucose in aqueous solution

B3.2 – Formation of **Cyclic Fructose**

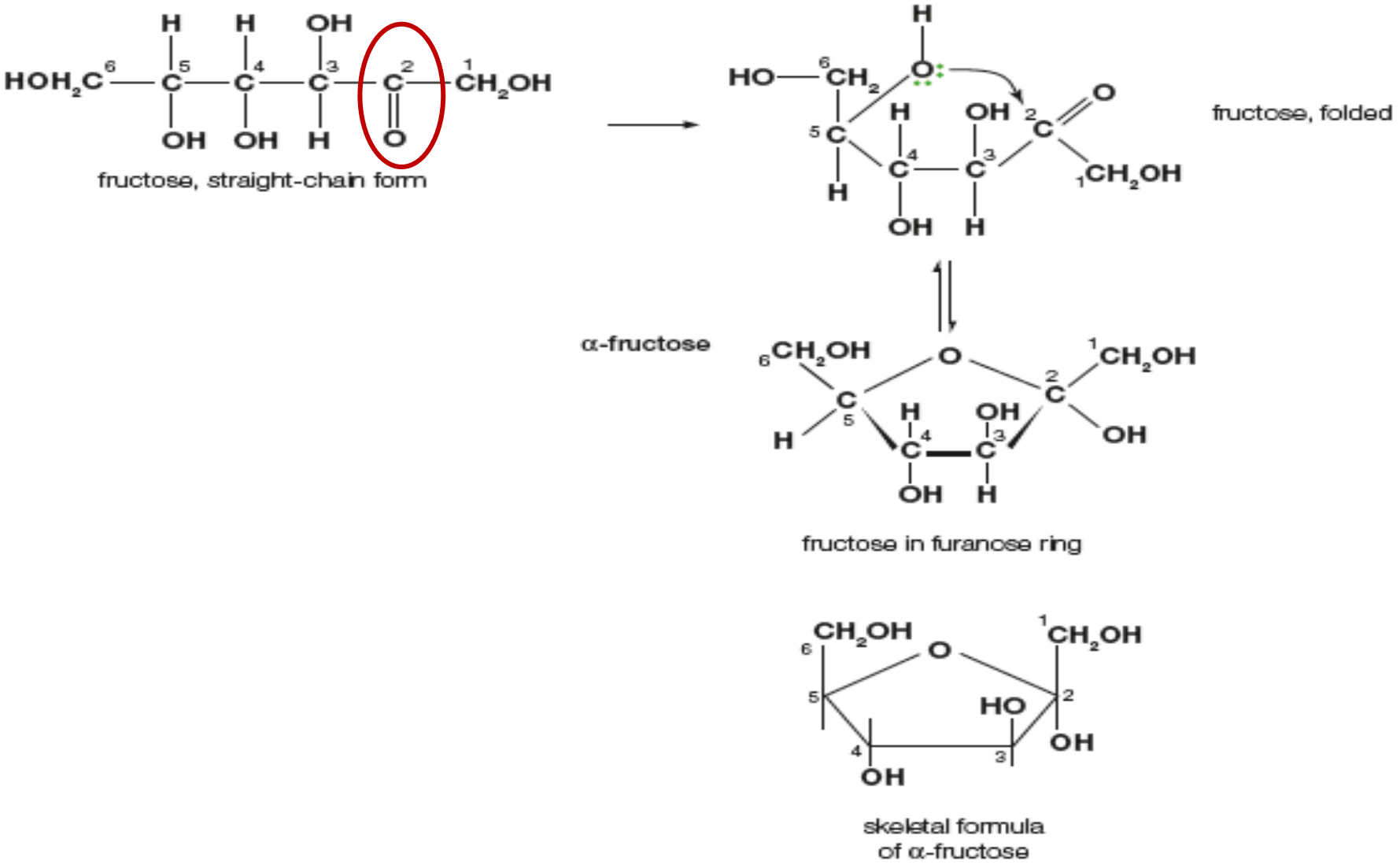


Figure 22.39 The structures of fructose in aqueous solution

B3.3 – Condensation of Monosaccarides

- **Disaccharides** consist of two monosaccharides joined by a **glycosidic linkage**, -O-.
- The reaction involves the elimination of water (a condensation reaction).
- The most common disaccharides are maltose, lactose, and sucrose
  - Maltose = two α–glucose residues
  - Sucrose = α–glucose and β–fructose
  - Lactose = glucose residue and galactose residue

B3

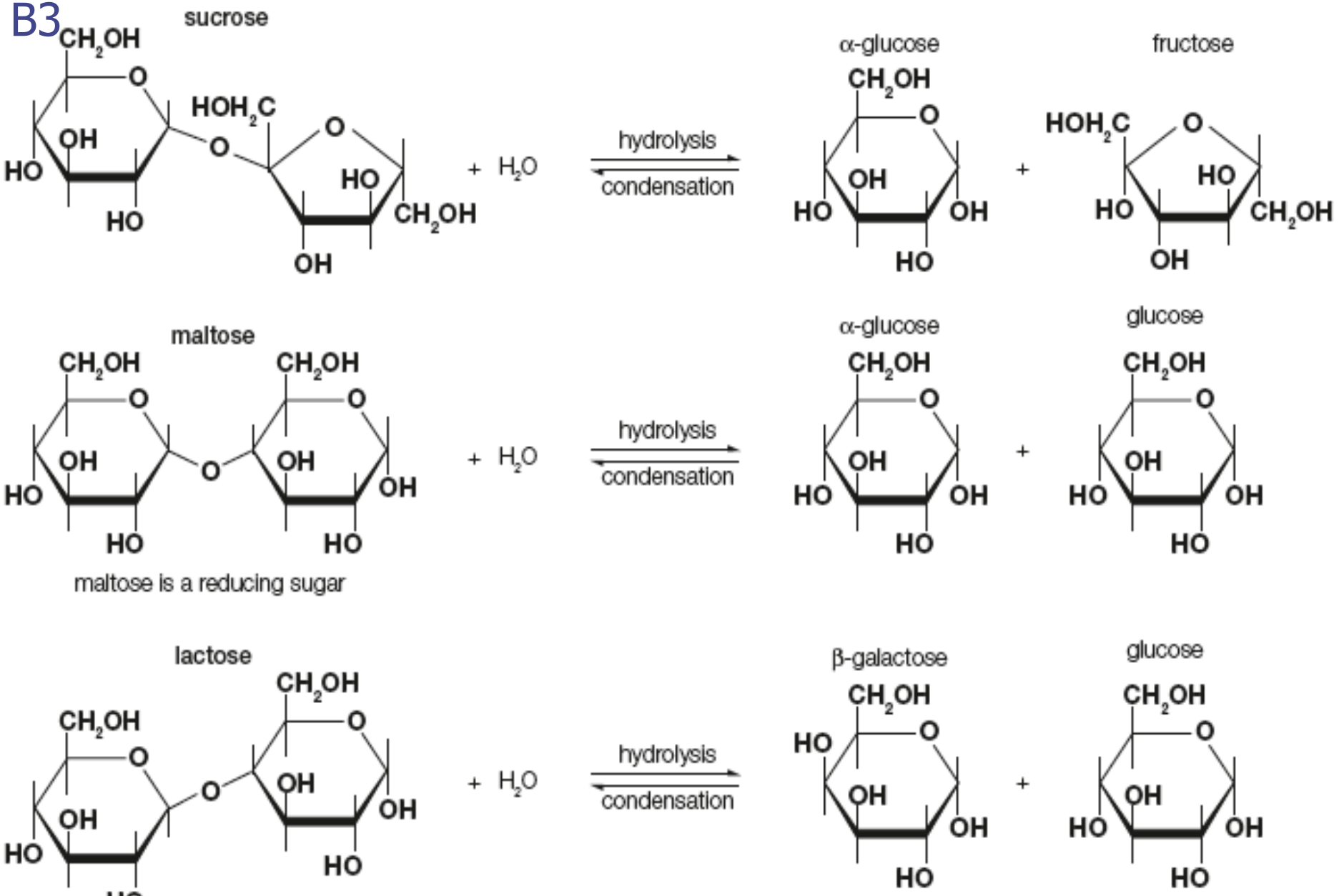


Figure 22.40 The formation of sucrose, maltose and lactose

B3.3 - Polysaccharides

- **Polysaccharides** are condensation polymers of monosaccharides
- Polysaccharides can produce monosaccharides (usually glucose) when put through enzyme or acid hydrolysis
- Three most common polysaccharides are starch, cellulose, and glycogen and are **ALL** formed from glucose residues
  - Starch: used to store glucose in plants (seeds, roots)
  - Glycogen: used to store glucose in animals (liver, muscle)
  - Cellulose: major component of cell walls, wood, cotton

B3.4 – Functions of Carbohydrates

- Carbohydrates act as energy sources for respiration (glucose is the major substrate).
- Fructose can also enter respiration
- The intermediate compounds formed during respiration can act as precursors for a range of molecules such as chlorophyll, hemoglobin, and DNA

B3.5 – Comparing starch and cellulose

- B3.5 **Compare** the structural properties of starch and cellulose and **explain** why humans can digest starch but not cellulose

B3.5 – **Starch** Structure

- **Starch** occurs in two forms: **amylose** and **amylopectin**.
  - **Amylose**: long unbranched chains in which all glucose units are bonded via **α-1,4-glycosidic linkages**
  - **Amylopectin**: branched molecule with the length of each branch being 24 and 30 glucose residues. The backbone contains **α-1,4-glycosidic linkages** BUT the branch points are **α-1,6-glycosidic linkages.**
    - Amylopectin has a similar structure to glycogen but not as branched and the molar mass in a big smaller

B3.5 – **Starch** Structure

STARCH: Repeating Each Unit

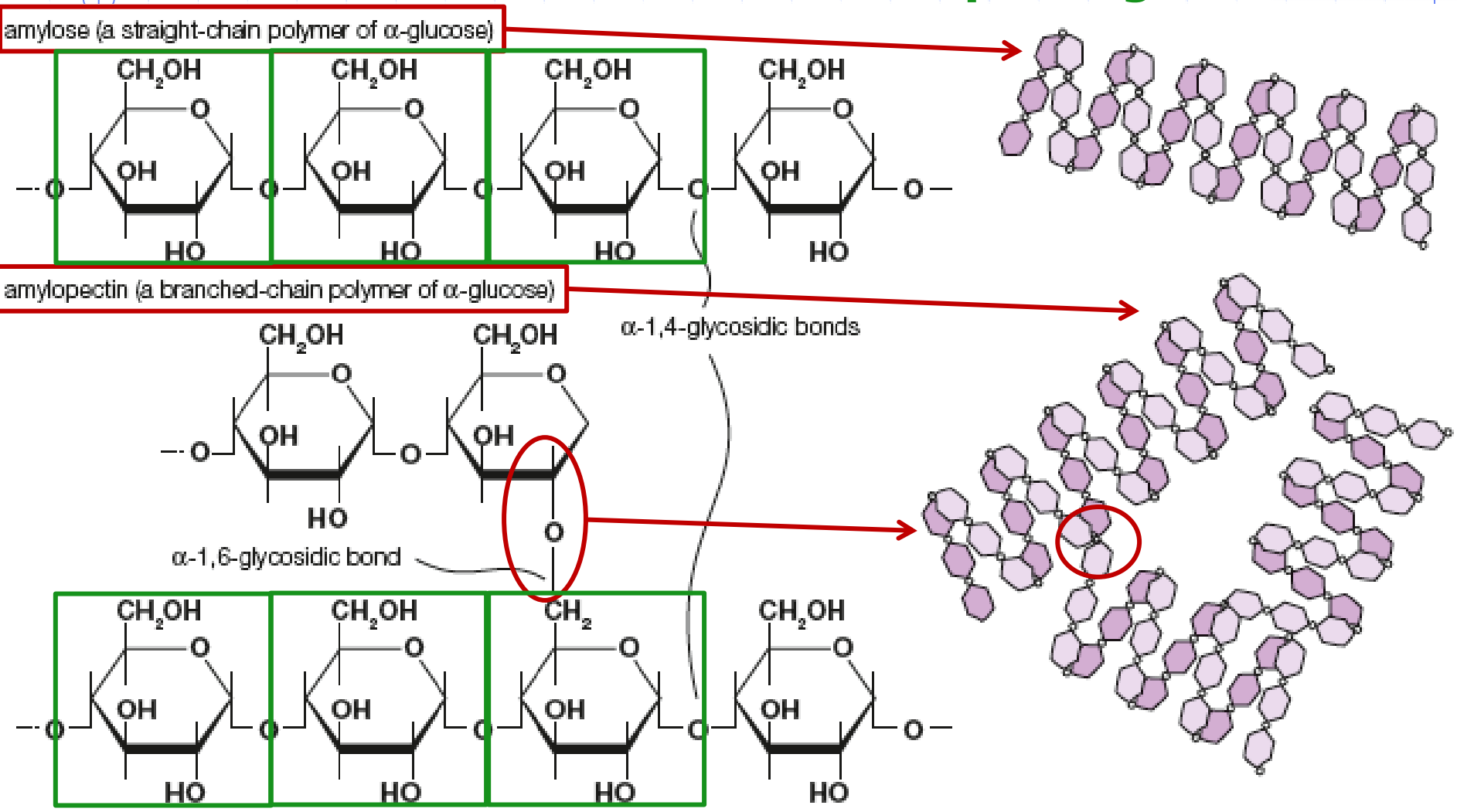


Figure 22.41 Structures of amylose and amylopectin

B3.5 – **Cellulose** Structure

- Cellulose is an unbranched polymer of glucose (like amylose) however the glycosidic linkages are **β-1,4 linkages**.
- These **β-1,4 linkages** that connect carbon atom 1 of glucose to carbon atom 4 of the other glucose, where the oxygen is in α the position on the carbon atom 1
- The change in bonding results in different properties. **Cellulose is insoluble in water** and **forms fibers** (Starch is soluble and is a powder.)

B3.5 – **Cellulose** Structure

CELLULOSE: Repeating Every Other Unit

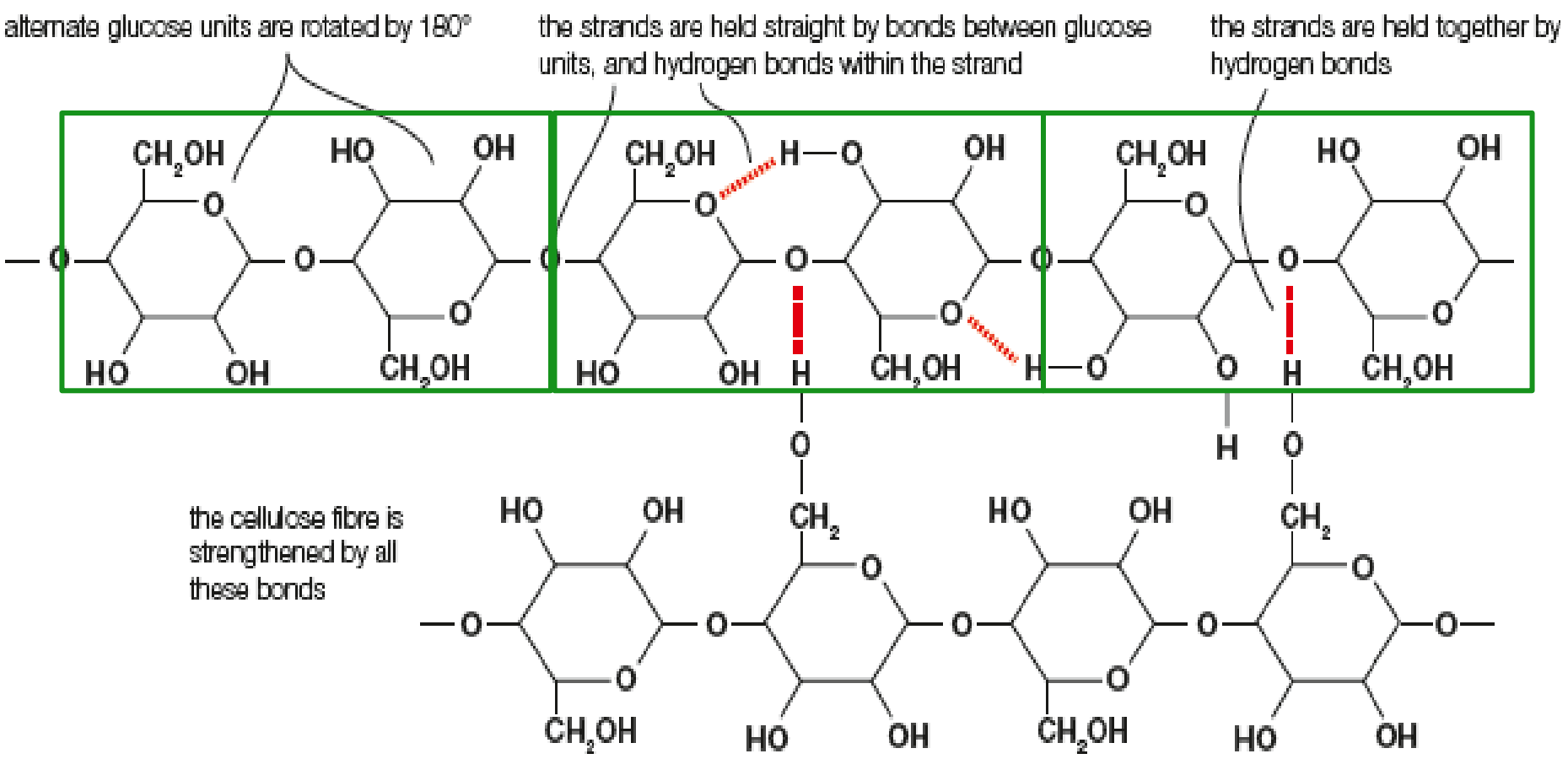


Figure 22.42 Structure of cellulose

B3.5 - Cellulose

- Animals contain **enzymes** that **degrade** amylmose and amylopectin into glucose BUT the enzymes DO NOT bind cellulose and they are **unable to hydrolyze cellulose**.
  - The material then passes through the digestive system as dietary fiber
  - Some animals secrete **cellulase**
    - Termites use to break down wood they eat
    - Cows use to digest grass they eat
    - Fungi can also break down cellulose

B3.6 – Dietary Fiber

- **Dietary Fiber** (known as **roughage**) is the indigestible portion of plant-based food that *retains water* and therefore aids motility (moving spontaneously and actively) and makes defecation easier
- Contains cellulose, hemicellulose, lignin and pectins.
  - Lignin: in wood, component of mature plant cell walls
  - Hemicellulose: similar to cellulose but formed from various monosaccharides
  - Pectin: binds adjacent plant cells together

B3.7 – Importance of Fiber

- As the fiber (being insoluble) passes through the small intestine it undergoes a varying degree of fermentation.
- This fermentation process produces a variety of short fatty acids that protect and promote the environment in the large intestine and stimulate the immune system.
- Dietery fiber is helpful in prevention of:
  - Diverticulosis, irritable bowel syndrome, constipation, obesity, chrones disease, hemoroids, diabetes mellitus, as well as lowers cholesterol levels

B3.7 – Fiber (Diverticulosis)

- **Diverticulosis** is characterized by the presence of pockets of tissue in the lining of the **colon** (large intestine) due to weakness in the muscle layers.
- Caused by pressure in the colon which may result from low fiber diets
- Symptoms include: bleeding, bloating and abdominal cramps after eating

B3.7 – Fiber (IBS)

- **Irritable bowel syndrom** (IBS) is a bowel disorder characterized by **abdominal pain** relieved by defecation.
- Cause not truly known, but may be in response to the presence of excessive microflora (small organisms) in the colon
- IBS may also be triggered by certain foods in the diet

B3.7 – Fiber (Chron's Disease)

- **Chron's disease** has similar symptoms to IBS and is genetically determined affecting both men and women. Common among those with Jewish and African-American decent.
- Autoimmune disease (overactive immune response to tissues normally present)
- The immune system responds to food and it's own bacteria as 'foreign.'
- Common complication is blockage of the intestine

B3.7 – Fiber (Hemorrhoids)

- **Hemorrhoids** (or piles) occurs when the veins in the rectum or anus become swollen and inflamed.
- As a result, defecation is painful and blood is present in the stools.
- Cause is pressure on the rectal veins often caused by increased straining during constipation or diarrhea.
- Cured by cutting off blood supply to the hemorrhoid so that it dies and enters the blood stream